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BIOLOGY OF THE SARATOGA SPITTLE INSECT

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[1/] This report contains the results of a cooperative study in which several agencies are interested. These include the Bureau of Entomology and Plant Quarantine and the Bureau of Plant Industry, Soils and Agricultural Engineering both of the Agricultural Research Administration, and the Forest Service, all in the United States Department of Agriculture; the Department of Economic Entomology and the Department of Plant Pathology both of the University of Wisconsin; and the Wisconsin Conservation Commission. The writer acknowledges the helpful suggestions and cooperation received from F. C. Craighead, H. J. MacAloney, H. C. Secrest, C. L. Fluke, A. J. Riker, R. H. Gruenhagen and C. A. Richards.

In recent years the Saratoga spittle insect, Aphrophora saratogensis (Fitch), has caused considerable injury to both red pine, Pinus resinosa Ait., and jack pine, P. banksiana Lamb., plantations of sapling size in many parts of the Lake States Region. In some places, naturally established reproduction has also been injured. Secrest (1944) first studied this problem and has recently reported the results of his work. During 1944, the writer took up the study of the insect aspects of the problem and is presenting in the present paper the results of his observations on the biology and ecology of the insect.

Insect Characteristics.-- Aphrophora saratogensis adults are tan or light brown insects 8 to 10 mm. long. The average length for 30 males measured was 8.7 mm. (range 8.1 to 9.1 mm.), whereas for a like number of females the average was 9.6 mm. (range 9.0 to 10.0 mm.). A light irregular stripe, slightly elevated and frequently broadening posteriorly, is usually present along the median line of the head and pronotum. This light line was absent on 9 individuals and indistinct on 24 others out of a total of 300 adults checked. The fore wings are varied with indistinct light spots which frequently form two wavy oblique bands on each. Probably the most constant characteristic is the shape of the male genital plates which, together with those for all the other known Aphrophora species, are figured by Doering (1941).

The nymphs are from about 1.7 to 2.0 (first instar) to 8 mm. (fifth instar) long. The most striking characteristic of the first

four instars is the scarlet color of the abdominal tergites. These are completely scarlet except for the dark colored terminal tergite and the pleural lobes. The extent of the melanin pigmentation of the latter is practically absent on first instar nymphs but then increases with each succeeding instar up through the fourth. Head, thorax (except sternites) and the legs are dark gray to black colored. The median line on head and thorax is light as are also the areas immediately around the compound eyes, the inner surface of each coxa, the outer surface of each trochanter, the area on femur and tibia adjacent to the articulation of the two, the empodia and the abdominal sternites. The compound eyes are scarlet.

The abdominal tergites of the fifth instar nymphs are mahogany colored. This condition appears to be caused by a light melanin pigmentation of the cuticula over the scarlet colored inner tissues. There is a reduction of the melanin pigmentation of the pleural lobes, thorax and head with the greater portion of the fore-wing pads and the clypeus being especially light in color. These observations suggest that, in the fifth instar nymphs, the black pigmentation becomes more uniformly distributed over all parts of the insect rather than remaining concentrated in certain areas of the body as occurs in the younger nymphs.

Distribution.-- According to Ball (1934), Aphrophora saratogensis is widely distributed occurring from Nova Scotia south to Florida, west through Ontario and the Lake States to British Columbia, and California. Doering, (1941), however, suggests that southern records

referring to A. saratogensis probably were concerned with A. detritus Walker.

Egg.-- Secrest (1944) reported that the eggs were laid in shallow slits or under scales of bark of sweet fern, Comptonia peregrina (L.) Coulter. The only eggs found by the writer, however, were those removed from gravid females. These unlaid eggs were about .6 mm. wide and 1.8 mm. long, one end was rather pointed, the long axis was slightly curved and the chorion was smooth. The first fully developed eggs were removed from females collected on July 24, which was just five days after the first copulating pair had been observed. During the whole season of adult activity, egg counts were made by dissecting field collected females from which the results presented in table 1 were obtained. The largest number of eggs removed from an individual was 27. All eggs counted were fully developed for only early in July were any partially developed eggs seen and these tiny eggs were not counted.

Table 1.-- Egg counts made from gravid spittle insects.

Date collected 1944	Average eggs per female	Insects Observed
	Number	Number
7/9-15	0	20
7/16-22	0	20
7/23-29	1.3	20
7/30-8/5	5.0	20
8/6-12	12.8	30
8/13-19	5.2	20
8/20-26	12.8	20
8/27-9/2	10.7	20

Nymphal Development.-- In 1944, the first nymphs were found on May 17 which was at the time the leaf buds were expanding on sweet fern, Comptonia peregrina, and blueberry, Vaccinium canadense Kalm. Pin cherry, Prunus pennsylvanica L., was beginning to bloom. From this time on through the developmental period, the rate of growth was followed and the results presented in table 2 obtained. In addition to size, a most useful characteristic for recognizing the different instars was the amount of black pigmentation on the pleural lobes. The whole caudal (IX) tergite, including the pleural lobes, was gray colored on the tiny first instar nymphs. In the second instar the pleural lobes of the eighth abdominal segment were also almost completely black with the dark portion extending slightly dorsad in the central part of the lobes. The remaining lobes were black on the cephalic and ventral margins (the lobes of the seventh segment approaching the degree of darkness of that of the eighth but lacked the median dorsal extension) decreasing in amount on each successive segment progressing cephalad. In the following two instars the extent of melanin pigmentation of the pleural lobes increased still more. Those of the seventh abdominal segment for the third instar and those of one or more additional segments for the fourth were almost completely black with the characteristic dorsal extension. The distinguishing color characteristics for the fifth instar have already been given under "Insect Characteristics." The length of the nymphs was rather variable depending on the degree to which the abdomen was extended; nevertheless, for 10 nymphs measured

for each instar the average lengths in mm. (with the ranges in parenthesis) were as follows: 2.0 (1.7-2.1), 3.0 (2.8-3.5), 4.3 (3.7-5.0), 5.8 (5.4-6.5), and 7.5 (6.6-8.1).

Table 2.-- Rate of Aphrophora saratogensis nymphal development during 1944.

Date	Instars					Nymphs Observed
	1	2	3	4	5	
	Percent					
May 17 to 26	100	0	0	0	0	955
" 27	97	3	0	0	0	128
" 29	12	88	0	0	0	81
" 31	5	95	0	0	0	191
June 2	0	41	59	0	0	162
" 5	0	7	93	0	0	111
" 8	0	2	98	0	0	57
" 10	0	3	67	30	0	57
" 12	0	0	30	70	0	36
" 14	0	1	30	69	0	89
" 16	0	0	5	94	1	346
" 19	0	0	2	81	17	83
" 20	0	0	1	74	25	85
" 21	0	0	1	39	60	190
" 26	0	0	0	7	93	229
July 1	0	0	0	1	99	368
" 4	0	0	0	0	100	524

Hosts.-- Ball (1928) reported that, in Florida, the nymphs of Aphrophora saratogensis had a different host (Woodwardia virginica (L.) Smith) than the pine feeding adults and, the same year, Plakidas and Smith (1928) listed the nymphs as being pests of strawberries in Louisiana. In the North Secrest (1944) found that Comptonia peregrina (L.) was the principal nymphal host. He also reported finding a few nymphs on a sprout of Populus grandidentata Michaux. During the 1944 season in northern Wisconsin, the writer found that the nymphs spittled up on many other hosts. These are listed in table 3 with the plants arranged according to the degree they were favored by the nymphs during the fifth stadium. Data on the success experienced in rearing the nymphs are also included. N. C. Fassett, curator of the herbarium at the University of Wisconsin, kindly checked and, when necessary, corrected the writer's identification of the host plants.

Table 3.-- Nymphal hosts of Aphrophora saratogensis.

Host plants	Nymphs per stem (5th instar)	Stems observed	Adults reared from late 4th instar nymphs	Insects observed
	Number	Number	Percent	Number
Salix humilis Marsh.	7.9	14	80	5
Comptonia peregrina (L.)	4.9	361	80	5
Rubus spp.	2.3	20	40	5
Epilobium angustifolium L.	2.1	11	--	0
Fragaria virginiana Duchesne	1.0	20	0	10
Pteridium aquilinum (L.) Kuhn.	0.7	60	40	5
Hieracium aurantiacum L. and H. scabrum Michx.	.7	22	60	5
Populus tremuloides Michx. (reproduction)	.7	30	--	0
Achillea lanulosa Nutt.	.7	20	--	0
Comandra umbellata (L.) Nutt.	.6	10	20	10
Erigeron ramosus (Walt.) BSP.	.3	32	--	0
Solidago juncea Ait. and S. nemoralis Ait.	.3	40	40 1/	5
Convolvulus spithamaeus L.	.2	30	--	0
Vaccinium canadense Kalm.	.2	100	0	10
Lactuca canadensis L.	.2	20	37 2/	19
Senecio plattensis Nutt.	.2	23	0 1/	5
Aster lindleyanus T. and G. and A. macrophyllus L.	.1	60	0 1/	5
Waldsteinia fragarioides (Michx.) Tratt.	.1	10	10 2/	21
Diervilla lonicera Mill.	.1	100	60 3/	5
Antennaria canadensis Greene	.1	80	0 1/	144+
Gaultheria procumbens L.	0	30	--	0
Anemone quinquefolia L.	0	5	0 1/	5
Anaphalis margaritacea (L.) B. and H.	--	0	--	0
Pedicularis canadensis L.	--	0	--	0

1/ Rearing adults from first instar nymphs was unsuccessful.
2/ Adults were reared from the first instar.
3/ Rearing adults from third instar nymphs was unsuccessful.

During the developmental period, the nymphal density decreased considerably on most of the host plants whereas for Comptonia the opposite occurred. The writer strongly suspects that the concentration of nymphs also increased on Salix, Populus, Rubus, Pteridium, Convolvulus and possibly a few others. No data were collected for these plants early in the season because the few that were examined at this time were uninfested. Apparently the nymphs left their spittle masses and migrated to the more favored hosts. During the fifth stadium, when the change of hosts was most pronounced, 105 nymphs were released on one side of a cage which covered an area of one square foot of ground. After 3 days, 78 of the nymphs had moved to the opposite side of the cage and were spittled up on sweet fern shoots located there, 15 were on an aspen shoot and 7 were on the Antennaria which was abundant over the whole area. These results indicate that it is possible for the nymphs - at least those in the fifth instar - to crawl through and/or over the litter, plants, etc. and find the favored hosts. During the first stadium, large numbers of nymphs were concentrated on individual plants. On one Lactuca plant, 51 nymphs were counted, 40 on another, while 30 and 25 first instar nymphs were collected from two aster plants. Nymphal densities on some of the hosts for the various instars are presented in table 4.

Table 4.-- Nymphal densities for the various instars on several of the host plants

Host Plants	Instars					Instars				
	1	2	3	4	5	1	2	3	4	5
	Nymphs per stem per observation					Stems observed				
	Number					Number				
Comptonia	.3	.3	2.3	2.3	4.9	186	80	35	44	361
Vaccinium	.4	.4	1.1	.1	.2	98	76	27	33	100
Antennaria	.5	.4	1.1	.2	.1	124	21	41	74	80
Hieracium	.8	.5	-	.2	.7	27	2	0	20	22
Comandra	1.1	.6	.5	0	.6	27	14	23	16	10
Solidago	1.3	1.6	.5	.4	.3	103	57	28	43	40
Senecio	1.3	1.0	-	.5	.2	24	15	0	13	23
Anemone	1.5	1.6	-	0	0	40	18	0	10	5
Aster	1.7	.3	.3	.1	.1	74	40	48	63	60
Diervilla	2.5	2.3	1.5	.6	.1	27	18	144	21	100
Waldsteinia	2.6	3.4	-	.7	.1	30	9	0	10	10
Lactuca	4.4	1.4	3.0	.2	.2	30	12	4	20	20

An estimation of the density of the nymphal host plants was made in the area where the pine had suffered most severely. These counts were made on 20 quarter mil-acre plots which were selected mechanically at intervals of 66 feet on two strips through the area. Total counts were made of all plants except Antennaria. The density of the latter was estimated by count-

ing the number of plants per 4 square inches and then estimating the area of each plot occupied by this plant. The final estimate was then computed from these data. The average plant densities as determined from these plots are presented in table 5.

Table 5.-- Density of herbaceous and low growing woody plants in the area where the injury to the pine was most severe.

Plants	Density per mil-acre
	Number [1/]
Antennaria	1325.0
Vaccinium	120.8
Aster	33.6
Comptonia	28.6
Gaultheria	21.6
Senecio	13.6
Diervilla	11.6
Solidago	9.4
Hieracium	3.2
Anemone	2.6
Rubus	2.2
Lactuca	1.6
Comandra	1.6
Salix	.5
Waldsteinia	.4

1/ Values are averages based on counts from 20 quarter-acre plots.

Although the nymphs did not feed on pines (the adult hosts), they were found to be concentrated in the vicinity of both red pines and jack pines. In addition to the data presented in table 6, similar results were obtained when counts were made in the vicinity of 10 single isolated trees (6 jack pine and 4 red pine). The latter were rather large - 12 to 16 inches d.b.h.

Table 6.-- Relation of nymphal density to the presence of pine.

Distance from pine plantation	Sweet fern infested	Stems Observed
Feet	Percent	Number
0	78	82
1 - 10	49	89
11 - 20	30	60
21 - 30	18	80
31 - 40	17	60
41 - 50	18	50
51 - 60	18	50
61 - 70	8	50
71 - 80	2	50
81 - 90	7	40
91 - 100	7	40

Red pine was the most favored host for the adults of Aphrophora saratogensis with jack pine being in second position. For 10 trees of each of these two species sampled, which were located adjacent to each other in the same area, the averages were 5.5 and 1.9 feeding punctures per square cm. of inner bark for the red pine and jack pine respectively. The difference was highly significant (t = 6.00). Comparable data for white pine (Pinus strobus L.) were not obtained because this species was seldom encountered in the plantations of the two-needled pines; nevertheless, a few indirect observations on this aspect were made by determining the nymphal population present beneath large (10- to 22-inch d.b.h.) red and white pines which were located adjacent to each other (50 to 100 feet apart). The data presented in table 7, together with general observations on insect activity and feeding punctures, indicates that white pine is not a favored host. Thus, on the basis of spittle insect feeding puncture counts, red pine was 3 times more heavily attacked than jack pine and, on the basis of nymphal counts beneath large trees, it was 7 times more favored than white pine. Fitch (1851) reported that adults were common on pitch pine and sometimes met with on white pine. In addition to jack pine, Doering (1941) refers to "tamarack or the evergreen tree of the North" as being listed as a host on specimens collected by R. H. Beamer in northern Minnesota.

Table 7.-- Aphrophora saratogensis nymphal density beneath five adjacent pairs of red and white pines.

Nymphal	Nymphs per plant beneath		Stems observed beneath	
	Red Pine	White Pine	Red Pine	White Pine
	Number	Number	Number	Number
Comptonia	3.5	.5	50	75
Aster	.6	0	20	21
Vaccinium	.5	.2	20	15
Pteridium	.4	.1	20	20
Waldsteinia	.3	0	20	20
Lactuca	.2	.1	10	10

Adult Activity.-- In 1944, adult emergence commenced on July 2 and continued thereafter for a period of almost one month. Data on the rate of emergence and the relative abundance of the adults throughout the remainder of the summer are presented in table 8.

Table 8.-- Rate of emergence and relative abundance of Aphrophora saratogensis adults during their period of activity.

Date 1944	Emergence	Stems Observed	Insects observed per 5-min. period	Observations
	Percent	Number	Number	Number
July 2-8	88	110	--	0
" 9-15	91	116	50	7
" 16-22	98	105	54	18
" 23-29	99	200	50	11
" 30-Aug. 5	100	100	44	16
Aug. 6-12	100	100	30	8
" 13-19	-	-	30	10
" 20-26	-	-	20	17
" 27-Sept. 2	-	-	19	3
Sept. 10-16	-	-	12	2
" 17-23	-	-	1	2

When feeding on the pine twigs, the insects would usually take positions down among the needles facing in the direction the needles sloped, i.e., toward the tips. Then if they were disturbed, they could easily slip out through the needles by leaping from the twigs. On the other hand, if they were facing toward the bole of a tree they would most likely become entangled in the needles when attempting to escape quickly.

Climatic and Biologic Controls.-- Aphrophora saratogensis had the habit of locating themselves in the vicinity of the root collars of the host plants where they fed and formed their spittle masses. Here, beneath the surface of the litter, moist conditions usually prevailed and, therefore, this habitat may have been more favorable for the nymphs. To check whether dry atmospheric conditions might be adverse for the nymphs, a series of humidity chambers with relative humidities of 0, 10, 25, 50, 75 and 100 percent were established (using different concentrations of sulphuric acid for controlling the humidity) and 5 fourth instar nymphs (caged on a sweet fern branch standing in a small bottle of water) placed in each chamber. Every two days the nymphs were transferred to fresh branches. The nymphs remained alive for one week in all of the treatments and during the following week they died at about the same rate. This observation suggests that extremely arid conditions were not unfavorable for the nymphs for a period of one week provided they could feed. Inability to rear any of the insects was due to the unsatisfactory condition of the food. The nymphs did not thrive on plants detached from the roots and placed in water.

Another possible natural control factor which may operate during the spring after the nymphs have become active is low temperature. A few observations made by the writer (table 9) supplement those made by Secrest (1944). Secrest used fifth instar nymphs, whereas the writer used third instar insects. In the present work a pint vacuum

bottle was adapted for the freezing chamber and into which the salt-ice freezing mixture was placed. The nymphs to be tested were collected spittled up on a portion of the host plant, placed in 20 cc. vials (still on the plants) and then lowered into the freezing mixture. The temperature drop was recorded with a good quality liquid (alcohol) thermometer. The bulb was placed adjacent to the insect with the stem extending to the outside through cork stoppers so that temperature readings could be made without disturbing the set-up. Third instar nymphs tested were found to be susceptible to temperatures in the twenties (table 9). Preconditioning the nymphs at 32 degrees F. for 12 hours reduced the mortality somewhat but did not lower the minimum at which 100 percent mortality occurred. The young nymphs in their natural habitat, however, were well protected so that the minimum temperatures which occurred there were considerably higher than the air temperatures a few inches above. During seven nights when the air temperature three inches above the surface of the litter in a weather shelter descended into the twenties or thirties, the minimum temperatures beneath the litter averaged 8.6 degrees F. higher. The day previous to one of these nights when a frost occurred, a total of 35 third instar nymphs were caged on 6 plants (5 nymphs on each) so that they were above the litter with 35 others similarly caged but covered with litter for the checks. That night the minimum air temperature was 27 degrees F. and remained below 30 for 5 hours (the quantity of cold was greater than in the individual tests described above) as compared with a minimum of 34

degrees F. beneath the litter. Mortality was 80 percent for the nymphs not protected, whereas no mortality occurred to the nymphs protected by the litter. On the basis of the above data the air temperature would have to descend to about 20 degrees F. before a 27 degree temperature would be reached beneath the litter. Such low temperatures during the period of nymphal development (last half of May and all of June), however, have not occurred during the past 15 years in the general area where this study was conducted. Seven of the 9 years previous to 1930, on the other hand, had temperatures 20 degrees or lower during the period of nymphal development but before this (1921) only 2 of 23 years experienced such severe frosts in the late spring. These data indicate that severe freezes in the late spring are not the usual occurrance in the area studied.

Table 9.-- Mortality of third instar Aphrophora saratogensis nymphs following momentary exposure to cold.

Temperatures	Mortality	Insects tested
Degrees F.	Percent	Number
32	0	10
30	38	21
28	50	12
25	62	14
23	75	12
20	100	13

Biological agencies likewise did not appear to be very active in reducing the spittle insect population. A few dead mumified nymphs were collected which suggested fungus activity, parasite larvae were removed from the abdomens of 3 out of a total of 220 adults dissected, and one spider was observed feeding on an adult.

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